

PTO/SB/05 (08-00)

Approved for use through 10/31/2002. OMB 0651-0032

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. PAT 308-2
First Inventor ZHANG, Hang et al
Title Method and System for ...
Express Mail Label No.

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original and a duplicate for fee processing)
2. ☐ Applicant claims small entity status.
See 37 CFR 1.27.
3. ☒ Specification [Total Pages 13]
(Preferred arrangement set forth below)
- Descriptive title of the invention
- Cross Reference to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to sequence listing, a table,
or a computer program listing appendix
- Background of the invention
- Brief Summary of the invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claim(s)
- Abstract of the Disclosure
4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 5]
5. Oath or Declaration [Total Pages 3]
a. ☒ Newly executed (original or copy)
Copy from a prior application (37 CFR 1.63 (d))
(for continuation/divisional with Box 17 completed)
b. ☐ DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s)
named in the prior application, see 37 CFR
1.63(d)(2) and 1.33(b)
6. ☐ Application Data Sheet, See 37 CFR 1.76

ADDRESS TO:

Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

7. ☐ CD-ROM or CD-R in duplicate, large table or
Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
a. ☐ Computer Readable Form (CRF)
b. Specification Sequence Listing on:
i. ☐ CD-ROM or CD-R (2 copies); or
ii. ☐ paper
c. ☐ Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. ☒ Assignment Papers (cover sheet & document(s))
10. ☐ 37 CFR 3.73(b) Statement of Power of Attorney
(when there is an assignee)
11. ☐ English Translation Document (if applicable)
12. ☐ Information Disclosure Statement (IDS)/PTO-1449 Copies of IDS Citations
13. ☐ Preliminary Amendment
14. ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
15. ☐ Certified Copy of Priority Document(s)
(if foreign priority is claimed)
16. ☐ Other:

17. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP)

of prior application No. _____

Prior application information:

Examiner _____

Group / Art Unit _____

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

18. CORRESPONDENCE ADDRESS

☒ Customer Number or Bar Code Label

or ☐ Correspondence address below

Name

26123

PATENT, TRADEMARK OFFICE

Address

City

State

Zip Code

Country

Telephone

Fax

Name (Print/Type)

Leslie Anne Kinsman

Registration No. (Attorney/Agent)

45,291

Signature

[Signature]

Date Nov. 3, 2000

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

JC772 U.S. PTO

JC841 U.S. PTO

09/704684

11/03/00

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 1 -

**METHOD AND SYSTEM FOR WIRELESS PACKET SCHEDULING WITH PER
PACKET QOS SUPPORT AND LINK ADAPTATION**

FIELD OF THE INVENTION

5 The present invention relates to packet scheduling in a telecommunications network. In particular, the present invention relates to a method and system for scheduling packets in a wireless telecommunications system.

BACKGROUND OF THE INVENTION

10 The design of current third generation (3G), and enhanced 3G, wireless access networks is driven by the need for high speed internet access. Increasingly, consumers are moving to wireless communications for the delivery of services and applications using conventional TCP/IP (Transmission Control Protocol/Internet Protocol). This trend is growing with the increase in internet-enabled wireless devices available to users, including cellular telephones, Personal
15 Digital Assistants (PDAs), and other devices. The applications that are now available or contemplated for wireless devices include access to the World Wide Web, video telephony, voice over IP, e-mail, etc.

20 However, wireless networks, whether fixed or mobile, suffer certain disadvantages over their wired counterparts in the delivery of IP applications. This is mainly due to the significantly greater lost or dropped packets in wireless networks, as compared to wireline. Such losses can be largely attributed to the changeable quality of the channel over which IP packets are sent. The wireless channel condition is highly dependent on the location of the wireless terminal in relation to its base station, and extraneous external or atmospheric interference. The combination of these factors can have a significant effect on the delivery of data services over wireless channels.

25 A further complication in wireless communication networks is caused by channels that are shared among multiple users. The high burstiness of packet-based applications requires statistical multiplexing on the forward link for increased system capacity and throughput on such channels.

A forward link packet scheduler is required to manage the output queues to provide the

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 2 -

desired forwarding of packets to users in a wireless network. Generally, a forward link scheduler performs two main functions. It makes scheduling decisions, using a scheduling algorithm, to determine which users' queued traffic should be scheduled for each transmission slot, and decides the link layer (layer 2) frame length/size (i.e., how many bits of data) of the selected user's traffic can be sent in each slot.

Current wireless packet schedulers have a very limited capability for handling Quality of Service (QoS) at a per application or service level, and are completely unable to support QoS at a per packet level. In terms of scheduling algorithms, current schedulers, such as those developed under the cdma2000 1xRTT standard and the Universal Mobile Telecommunications System (UMTS), are purely driven by latency of traffic to users, or, in the case of High Data Rate (HDR), are driven by channel condition with fairness consideration. These algorithms do not consider per packet Quality of Service (QoS). In terms of determining the layer 2 frame length/size, current systems determine the layer 2 frame length either by fixed physical layer frame structure (e.g., 1xRTT, UMTS), or by link adaptation which considers both physical layer frame structure and channel condition (e.g., HDR, and Enhanced Data Rates for GSM Evolution (EDGE)). In addition, current schedulers are unable to provide a tight match between per IP QoS and resource allocation, are unable to support multiplexing on a packet basis, and are unable to support per packet based Automatic Repeat reQuests (ARQs). These existing wireless packet schedulers do not take into consideration both per packet QoS and link adaptation.

It is, therefore, desirable to provide a scheduler that can support per packet QoS, can support link adaptation on a per packet basis, can support packet-based multiplexing, and can support per packet-based ARQs.

SUMMARY OF THE INVENTION

It is an object of the present invention to obviate or mitigate at least one disadvantage of previous systems and methods for wireless packet scheduling. In particular, it is an object of the present invention to provide a system and method that permits scheduling on a per packet basis, and that permits packet multiplexing in a single frame or slot.

In a first aspect, the present invention provides a method for scheduling packets for

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 3 -

transmission over a forward link in a wireless communication system. The method consists of determining a wireless quality of service condition, or per packet QoS, for each of a plurality of packets awaiting transmission to a terminal. For each available frame, a reported channel condition for a forward link from the terminal is received. From the reported channel condition, a link mode for transmission to the terminal can be determined. Then, each of the plurality of packets is scheduled in order of its respective wireless quality of service condition, and at the determined link mode, for transmission in a physical layer frame.

In presently preferred embodiments, the quality of service condition is stored as a packet tag associated with each of the plurality of packets. The packet tag includes a start time and a finish time that are functions of a packet delay bound, an arrive time and a delay budget for each packet. A deadline for each packet can then be calculated as a function of the start time and a current system time.

Typically, the method of the present invention assumes that there are also further packets that are awaiting transmission to other terminals. Generally, packets are scheduled in order of their deadlines, their wireless quality of service conditions, the channel condition for the terminal to which they are to be sent, or a combination of these factors as determined by the operator of the wireless access network.

In a further aspect, the present invention provides a scheduler for scheduling packets for forward link transmission in a wireless communication network. The scheduler consists of a packet tag computation unit for determining a wireless quality of service condition for each of a plurality of packets awaiting transmission to a terminal, and a link mode determination unit for receiving a reported channel condition for a forward link from the terminal, and for determining a link mode for transmission to the terminal according to the reported channel condition. A scheduling unit then schedules each of the plurality of packets in order of its respective quality of service condition, and at the determined link mode, for transmission in a physical layer frame.

In yet a further aspect, there is provided a wireless access network. The wireless access network includes a radio transceiver for sending a physical layer frame to a terminal. The frame is assembled by the above-described scheduler.

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 4 -

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example only, with reference to the attached figures, wherein:

Fig. 1 is a diagram of a wireless network configuration for communication between a wireless terminal and an application server;

Fig. 2 is a diagram of the scheduler function of an embodiment of the system of the present invention;

Fig. 3 shows queued packets for four users according to an example of the method of the present invention;

Fig. 4 shows the scheduling of the packets in Fig. 3;

Fig. 5 shows queued packets for four users according to a further example of the method of the present invention; and

Fig. 6 shows the scheduling of the packets in Fig. 5.

DETAILED DESCRIPTION

Generally, the present invention is a method and system for scheduling data in the down, or forward, link, on a per packet basis in a wireless telecommunications network. A wireless packet scheduler is presented that can determine the order of packets to be sent from multiple queues based on per packet QoS, real time channel condition an/or real time buffer occupancy.

The scheduler can also determine the necessary support link adaptation on a per packet basis based on per packet QoS and the channel condition. The scheduling system and method can take into consideration both upper layer per packet QoS, such as packet delay bound, and the real time channel condition (e.g., C/I) for each mobile terminal. The method of the present invention can also determine the layer 2 frame length for each scheduled packet.

As used herein, link adaptation is a protocol whereby the physical layer link modulation and code rate are dynamically changed based on current channel condition for each mobile, in order to satisfy a required wireless link QoS, such as frame error rate (FER), bit error rate (BER) or block error rate (BLER), and to maximize data throughput.

Fig. 1 shows a typical wireless network configuration linking a number of wireless

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 5 -

terminals 100 to a number of servers 102 through a wireless access network 104. As will be understood by those of skill in the art, Fig. 1 is a simplified overview of a wireless network configuration. Typically, a server 102, or terminal 100 in the case of terminal-terminal communications, sends data to the wireless access network 104 from which the data is transmitted over a radio link 106 to a terminal 100. Wireless access network 104 typically includes one or more base stations, or hubs, including suitable processing means and radio frequency hardware, as is well known to those of skill in the art. A wireless packet scheduler 200 is included in the wireless access network 104, in the data link layer, to schedule the transmission of data packets to appropriate terminals 100.

The system and method of the present invention presume that the network is packet-based, such as TCP/IP-based. As used herein, a terminal can be any suitable wireless device, such as a cellular telephone or wireless access protocol (WAP) enabled device capable of executing real time applications, such as video conferencing and voice over IP, and/or non-real time applications, such as a file transfer or e-mail. The applications provided by application servers 102 can, if desired, support multiple users simultaneously, and multiple applications can be supported for each user.

The payload data is provided to the link layer by the application layer. It is assumed that the packets so received include information relating to their per packet QoS. The per packet QoS can be based on, for example, each packet's acceptable packet loss rate, packet delay bound and/or other parameters. As used herein, packet delay bound is the acceptable delay in the wireless link for a given packet. For example, real time packets could have a packet delay bound of 70 ms, while non-real time packets could have a packet delay bound of up to 3 s. In such an example, a higher priority, or QoS, would be given to packets from real time applications than to packets from non-real time applications if the per packet QoS was based on packet delay bound.

Fig. 2 is a block diagram of the wireless access network 104, including the scheduler 200 of the present invention. Data packets are received from the application layer for a number of users A, B to n. The packets are received by a packet classification unit 204 from the application layer, and include appropriate per packet QoS information. The packet classification unit 204 classifies each packet according to its respective per packet QoS information, and passes a

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 6 -

packet classification, or per packet QoS parameters, 205 to a packet tag computation unit 208 in the scheduler 200, which associates an appropriate packet tag to each incoming packet. The QoS parameters 205 include the per packet QoS, the packet delay bound, and the packet arrive time in the queue. The packet tag, also referred to herein as the wireless quality of service condition, includes the per packet (or wireless) QoS parameters 205 for the packet, as well as the packet's start time and a finish time. The start time and finish time are derived from the arrive time of the packet, the packet delay bound, and any delay budget (e.g., delay budget for retransmission or delay budget for fragmentation) for the packet. Meanwhile, the incoming packets are stored in buffer(s) 202 while they await transmission. Typically, one queue is set up for each user or terminal. Alternatively, queues can be determined according to per packet QoS, or other factors. The scheduler 200 receives channel condition information 203 from each terminal, for each frame or slot. The channel condition information 203 is used by a link mode determination unit 201 to determine an appropriate link mode for each channel.

The packet tag, channel condition information 203, buffer occupancy information 207 from the buffers 202, retransmission information 209 and other information 211, such as the packet loss rate, are supplied to a scheduling unit 212 that applies a scheduling algorithm, or set of scheduling rules, to provide scheduling decisions 206 that are returned to the buffers 202 to schedule the packets. The scheduling unit 212 determines a deadline for each packet, and schedules the packets according to their deadlines, finish times, per packet QoS, and/or other factors, as determined by the scheduling algorithm. The deadline is derived from the packet's start time and the current system time (the computation of packet deadlines is discussed in greater detail below). As used herein, "scheduling" includes both selecting and ordering packets for transmission, allocating them to a layer 2 (L2) frame, and specifying a link mode for each channel. The assembly of the scheduled packets is effected by multiplexer 210 before being sent to the physical layer (layer 1) for transmission.

As with conventional schedulers, the scheduler 200 performs on a per slot basis. The link mode for each channel, as determined by link mode determination unit 201, is typically found by lookup in a predetermined table according to the reported channel condition for each terminal.

Generally, the scheduling method of the present invention is as follows. Upon arrival at

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 7 -

the scheduler 200, each packet is labelled by a tag provided by the packet tag computation unit 208. For example, the tag can include a start time and a finish time that are functions of the packet delay bound, packet length, and/or other parameters of the per packet QoS. For each slot, the scheduler 200 then decides which packets should be scheduled first based on a deadline that is derived from the packet tag and the current system time. Those packets that must be sent in the current frame are first identified. The packets that must be sent in the current frame include, for example, those where the finish time is equal to the current system time, and those where the deadline is zero. The scheduler 200 also determines the link mode for each identified packet based on the channel condition for transmitting each identified packet. This determines the L2 frame size for each identified packet. If there are resources left after these packets are scheduled for the current slot, the scheduler 200 can then repeat the above steps for unscheduled packets according to their wireless quality of service conditions, or for packets with the best available channel condition, in accordance with the scheduler algorithm, until the slot or frame is filled. The information used by the scheduler 200 generally includes the channel condition of each user or terminal, any retransmission information, the wireless packet QoS conditions, and the packet sizes. This process is repeated at each slot for packets that remain in the queues, and for new packets that have arrived in the queues.

For example, the packet tag can be determined as follows. The k th packet in i th queue is $P_{i,k}$. Its arrive time $t_{i,k}^a$ is the system time when the packet enters a queue. The finish time $t_{i,k}^f$ is $t_{i,k}^a + D$, where D is the packet delay bound; and, the start time $t_{i,k}^s$ is $t_{i,k}^f - D_{i,k}^{ret} - D_{i,k}^{frag}$, where $D_{i,k}^{ret}$ is the estimated delay budget for retransmission for packets that can be retransmitted (i.e. non-real time packets), and $D_{i,k}^{frag}$ is the estimated delay budget for fragmentation, if fragmentation is supported. The packet deadline $t_{i,k}^d$ is equal to the current system time t minus the start time $t_{i,k}^s$.

In a first example of the method of the present invention, the scheduling is primarily deadline driven. The packet with the minimum deadline $t_{i,k}^d$ as determined by its start time among all queues is selected first. The channel condition for a particular user is used to determine the physical layer link modulation and code rate for the packets sent to that user. If any resources are left after the first packet is scheduled, the scheduler 200 continues to schedule

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 8 -

packets based on the packet deadlines until an L2 frame is filled.

In a second example of the method of the present invention, the scheduling is both deadline and per packet QoS driven. The rules are as above for the first method, however, packets can have either a per packet QoS of Q1 or Q2. To meet the per packet QoS and to resolve conflicts between packets, the following additional rules are added. Q1 packets have a higher priority than Q2 packets (for example, Q1 packets are real time packets, and Q2 packets are non-real time packets). Therefore, when both a Q1 packet and a Q2 packet have the same minimum deadline, the Q1 packet has priority over the Q2 packet. If there is a conflict between Q1 packets, a Q1 packet is randomly selected. If there is a conflict between Q2 packets, a Q2 packet is randomly selected. If a packet's deadline $t_{i,k}^d$ less than or equal to zero, it must be sent in the current frame, provided its finish time $t_{i,k}^f$ is greater than or equal to the current system time t . If the finish time $t_{i,k}^f$ is less than the current system time t , the packet is dropped.

An illustration of the operation of the scheduler using the scheduling algorithm of this second example is illustrated in Figs. 3 and 4. Fig. 3 shows a number of packets that are queued for transmission. Packets for four users: User A, User B, User C and User D are shown. User A has three packets queued: packet P1 is a Q2 packet, packets P8 and P4 are Q1 packets. User B also has three queued packets: packets P9 and P0 are Q1 packets, and packet P5 is a Q2 packet. User C has a Q2 packet P6 waiting for transmission, and User D has four packets: packets P7 and P2 which are Q1 packets, and packets P10 and P3 which are Q2 packets. For the purposes of this example, it is assumed that the channel condition for each user is the same, and, therefore, that each user has the same link adaptation rate.

Packet P0 has a deadline $t_{i,k}^d = 0$, and is the first to be allocated to L2 frame 400, as shown in Fig. 4. Packets P1, P9, and P5 all have deadlines of "1". However, packet P9 is a Q1 packet, while packets P1 and P5 are Q2 packets. Therefore, packet P9 is next scheduled. A random selection is then made between packets P5 and P1, and packet P5 is scheduled, followed by packet P1. Packets P4 and P8 each have deadlines of "2", and are both Q1 packets. Random selection between them leads to packet P4 being scheduled before packet P8. Packets P2, P3, P7, and P6 are then scheduled based on their deadlines such that frame 400 is filled. The remaining packet P10 remains in User D's queue for scheduling in the next frame. As an

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 9 -

alternative to random selection among packets having equal QoS and deadlines, the scheduler 200 can choose those packets that are for the same User, as opposed to packets for Users who do not have a currently scheduled packet. This can reduce overhead by reducing the number of headers required, since a single user's packets can be sent in series.

5 In a further example of a scheduling algorithm according to the present invention both packet deadlines and channel condition are taken into consideration to determine the scheduling. The channel condition is also used to determine the link adaptation for each user's packets. First, all packets with a deadline $t_{i,k}^d = 0$ are scheduled. The packet destined to the user with the best relative channel condition is scheduled first, followed by that with the next best condition, etc. If 10 further space remains in the frame, the user with the best channel condition is next selected. All available packets for this user are scheduled, followed by the packets for the user with the next best channel condition, etc. Otherwise, the conflict resolution rules are as outlined above for the second example.

15 Figs. 5 and 6 provide an illustration according to this example. As shown in Fig. 5, packets are again queued for Users A, B, C, and D with their per packet QoS indicated in parentheses. User A has the worst reported channel condition, User B has the next worst reported channel condition, User C has the best reported channel condition and User D has the second best reported channel condition.

20 Both packets P0 and P4 have deadlines of "0". However, User B's channel condition is better than User A's. Therefore, packet P0 is scheduled first in to L2 frame 600, and packet P4 is scheduled next, both at their appropriately calculated link mode. There are no packets remaining with a deadline of zero, therefore the packets for the user with the best channel condition are next selected. Since User C has the best channel condition, User C's packet P6 is next scheduled. User D now has the best channel condition, so User D's packets P2, P3, P7, and P10 are then 25 scheduled. The other packets, packets P9 and P5, belonging to User B are next scheduled. This leaves User A packets P8 and P1. Packet P1 is scheduled first, based on its deadline. There is still some space left in frame 600, but not enough for all of packet P8. Therefore, packet P8 is fragmented and fragment P8' is scheduled for transmission in frame 600. The remaining fragment of packet P8 remains in User A's queue for transmission in a subsequent frame.

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-2

- 10 -

As will be apparent to those of skill in the art, numerous variations can be made to the above-described scheduling algorithms. More complex algorithms can result in finer granularity and better use of bandwidth, but may do so at a greater processing cost. The present invention permits a scheduler to perform upper layer traffic scheduling on a per packet basis, taking into account both per packet QoS and real time channel condition. As shown in the examples, the method and system of the present invention enables multiplexing on a per packet basis. It is believed that this can increase system capacity. Link adaptation on a per packet basis is also facilitated. The present invention is particularly applicable to enhanced 3G products such as HDR, and to future mobile and fixed wireless access products.

The above-described embodiments of the present invention are intended to be examples only. Alterations, modifications and variations may be effected to the particular embodiments by those of skill in the art without departing from the scope of the invention, which is defined solely by the claims appended hereto.

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-0

- 11 -

What is claimed is:

1. A method for scheduling packets for transmission over a forward link in a wireless communication system, comprising:

5 (i) determining a wireless quality of service condition for each of a plurality of packets awaiting transmission to a terminal;

(ii) receiving a reported channel condition for a forward link from the terminal;

(iii) determining a link mode for transmission to the terminal according to the reported channel condition; and

10 (iv) scheduling each of the plurality of packets in order of its respective wireless quality of service condition, and at the determined link mode, for transmission in a physical layer frame.

2. The method of claim 1, wherein the determination of the wireless quality of service condition includes assigning a packet tag to each of the plurality of packets.

15 3. The method of claim 2, wherein the packet tag includes a start time and a finish time.

4. The method of claim 3, wherein scheduling includes determining a deadline for each of the plurality of packets as a function of their respective start times and a current system time.

20 5. The method of claim 4, wherein the scheduling includes scheduling the plurality of packets in order of their respective deadlines.

25 6. The method of claim 1, wherein further packets are scheduled for transmission to other terminals.

7. The method of claim 6, wherein the scheduling includes determining which of the terminal and the other terminals has a best reported channel condition.

Nortel Ref.: 12736ROUS010

Attorney Docket No.: PAT 308-0

- 12 -

8. The method of claim 6, wherein the scheduling includes scheduling packets destined to the determined terminal before scheduling packets to a remaining terminal.

9. A scheduler for scheduling packets for forward link transmission in a wireless communication network, comprising:

a packet tag computation unit for determining a wireless quality of service condition for each of a plurality of packets awaiting transmission to a terminal;

a link mode determination unit for receiving a reported channel condition for a forward link from the terminal, and for determining a link mode for transmission to the terminal according to the reported channel condition; and

a scheduling unit for scheduling each of the plurality of packets in order of its respective wireless quality of service condition, and at the determined link mode, for transmission in a physical layer frame.

10. The scheduler of claim 9, wherein the packet tag computation unit determines a start time and a finish time for each of the plurality of packets, the start time and finish time being functions of the respective packet delay bound and an arrive time for each of the plurality of packets.

11. The scheduler of claim 10, wherein the scheduling unit determines a deadline for each of the plurality of packets as a function of its respective start time and a current system time.

12. The scheduler of claim 9, wherein the link mode determination unit receives a plurality of reported channel conditions for a plurality of terminals.

13. The scheduler of claim 12, wherein the scheduling unit considers the plurality of reported channel conditions.

14. A wireless access network, comprising:

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-0

- 13 -

a radio transceiver for sending a physical layer frame to a terminal, and

5 a scheduler for scheduling packets for transmission to the terminal, the scheduler having a packet tag computation unit for determining a wireless quality of service condition for each of a plurality of packets awaiting transmission to the terminal; a link mode determination unit for receiving a reported channel condition for a forward link from the terminal, and for determining a link mode for transmission to the terminal according to the reported channel condition; and a scheduling unit for scheduling each of the plurality of packets in order of its respective wireless quality of service condition, and at the determined link mode, for transmission in the physical layer frame.

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176

Nortel Ref.: 12736ROUS01U

Attorney Docket No.: PAT 308-0

- 14 -

ABSTRACT

A method and system for scheduling data in the down, or forward, link, on a per packet basis in a wireless telecommunications network. The scheduler determines the order of packets to be sent from multiple queues based on per IP QoS, real time channel condition and real time buffer occupancy. The scheduler determines the necessary support link adaptation on a per packet basis based on per packet QoS and the channel condition. The scheduling system and method take into consideration both upper layer per packet QoS, for example packet delay bound, and the real time channel condition (C/I) for each mobile terminal. The method of the present invention also determines the layer 2 frame length for each scheduled packet.

20000317 16:19 FAX 6132308842

1/5

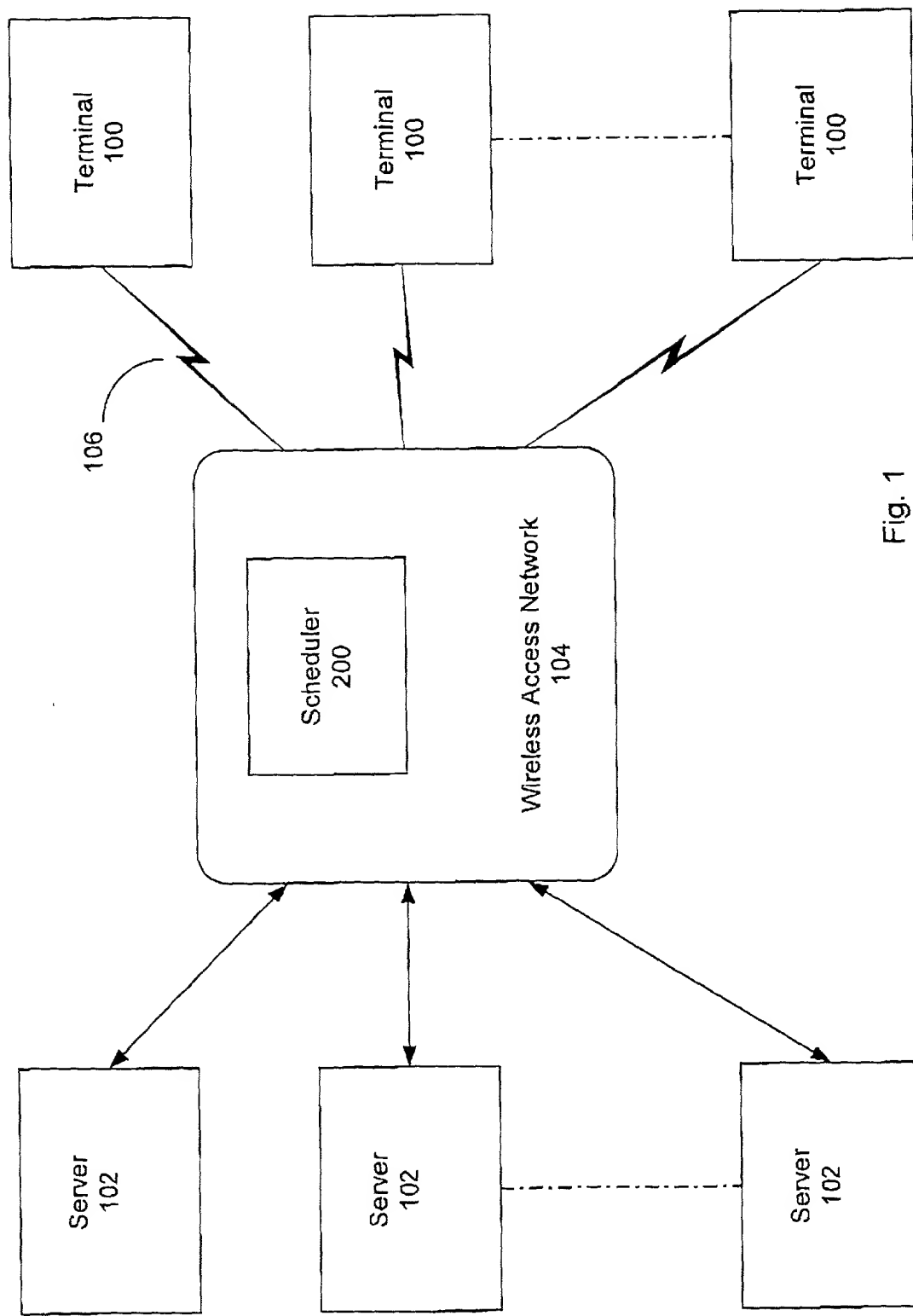


Fig. 1

Doc # 4644268

2/5

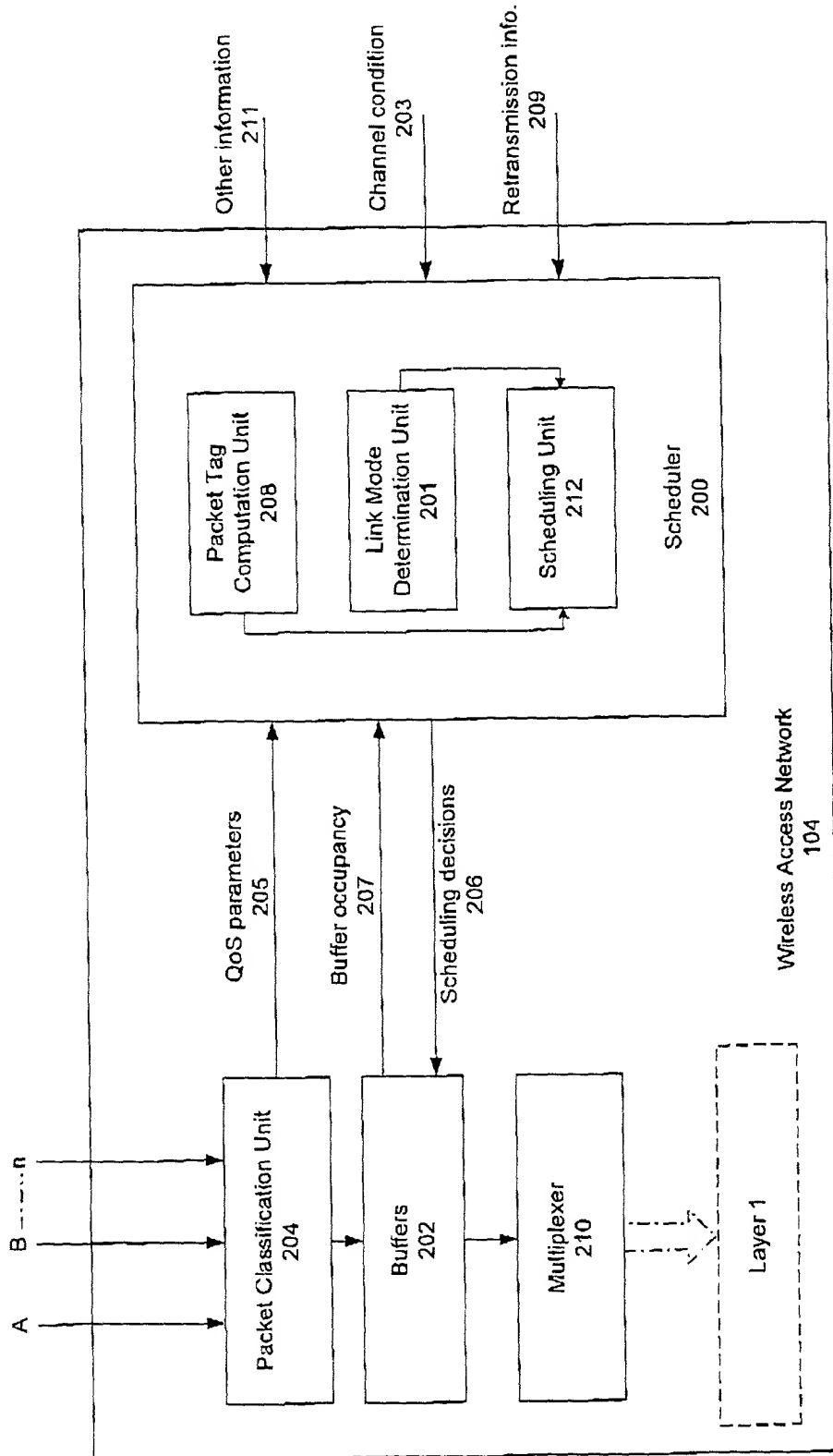


Fig. 2

3/5

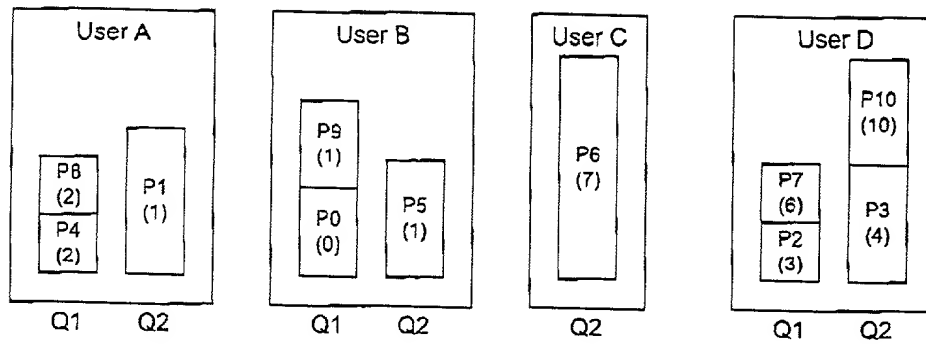


Fig. 3

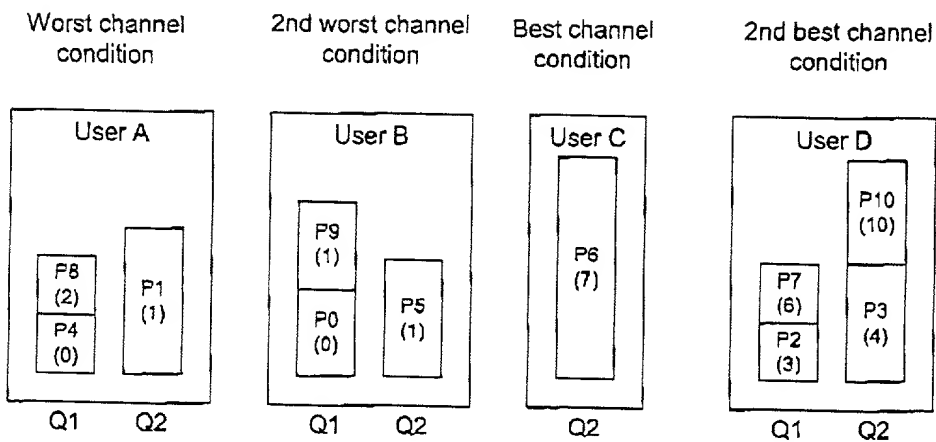


Fig. 5

4/5

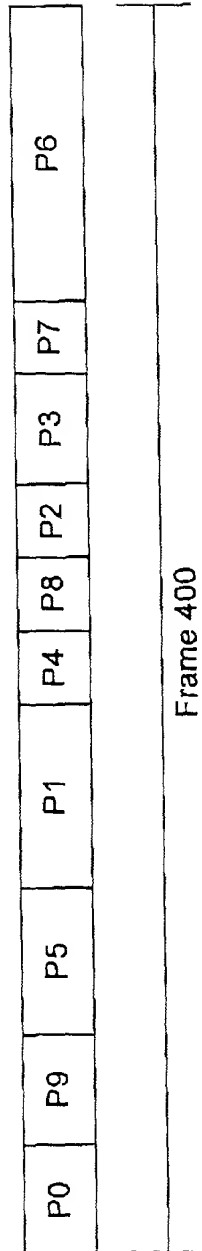


Fig. 4

5/5

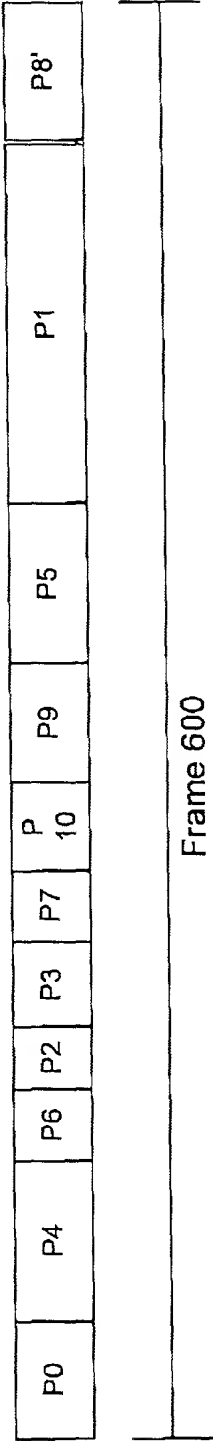



Fig. 6

NOV 03 '00 11:36AM NORTEL 613 765 2592

P.2

Please type a plus sign (+) inside this box → 

PTO/SB/01 (10-00)

Approved for use through 10/31/2002. QMB 0651-0032

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)	Attorney Docket Number PAT 308-2
	First Named Inventor ZHANG, Hang et al.
	COMPLETE IF KNOWN
	Application Number /
	Filing Date
	Group Art Unit
<input checked="" type="checkbox"/> Declaration Submitted with Initial Filing OR <input type="checkbox"/> Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)	Examiner Name

As a below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**METHOD AND SYSTEM FOR WIRELESS PACKET SCHEDULING WITH
PER PACKET QOS SUPPORT AND LINK ADAPTATION**

(Title of the invention)

the specification of which

☒ is attached hereto

OR

☐ was filed on (MM/DD/YYYY)

as United States Application Number or PCT International

Application Number and was amended on (MM/DD/YYYY)

(if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.55, including for continuation-in-part applications, material information which becomes available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 355(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
			<input type="checkbox"/>	YES <input type="checkbox"/>	NO <input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	<input type="checkbox"/> Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

[Page 1 of 2]

Burden Hour Statement: This form is estimated to take 25 minutes to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

NOV 03 '00 11:37AM NORTEL 613 765 2592

P.3

Please type a plus sign (+) inside this box → ☒PTO/SB/01 (10-00)
Approved for use through 10/31/2002, OMB 0651-0032U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.**DECLARATION — Utility or Design Patent Application**Direct all correspondence to: ☒ Customer Number or Bar Code Label  OR ☐ Correspondence address below

Name

26123

PATENT TRADEMARK OFFICE

Address

Address

City

State

ZIP

Country

Telephone

Fax

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR:

☐ A petition has been filed for this unsigned inventorGiven Name Hang
(first and middle (if any))Family Name ZHANG
or SurnameInventor's
Signature

Date Nov 3rd, 2000

Residence: City Ottawa

State ON

Canada
CountryChinese
Citizenship

Mailing Address 1259 Terrebonne Drive

Mailing Address

City Ottawa

State Ontario

ZIP K2C 0S1

Country Canada

NAME OF SECOND INVENTOR:

☐ A petition has been filed for this unsigned inventorGiven Name Peiying
(first and middle (if any))Family Name ZHU
or SurnameInventor's
Signature

Date Nov 3rd, 2000

Residence: City Kanata

State ON

Canada
CountryCanadian
Citizenship

Mailing Address 16 Pebble Creek Crescent

Mailing Address

City Kanata

State Ontario

ZIP K2M 2L4

Country Canada

☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto.

NOV 03 '00 11:37AM NORTEL 613 765 2592

P.4

Please type a plus sign (+) inside this box → ☐

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

PTO/SB/02A (3-97)

Approved for use through 8/30/98. OMB 0851-0032
Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

DECLARATION	ADDITIONAL INVENTOR(S) Supplemental Sheet Page 1 of 1
--------------------	--

Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor			
Given Name (first and middle (if any))		Family Name or Surname			
Shalini S.		PERIVALWAR			
Inventor's Signature	Shalini			Nov 3 2000 Date	
Residence: City	Ottawa	State	ON	Country	Canada
Post Office Address	71 Russell Avenue East				
Post Office Address					
City	Ottawa	State	ON	ZIP	K1N 7X2
				Country	Canada
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor			
Given Name (first and middle (if any))		Family Name or Surname			
Inventor's Signature				Date	
Residence: City		State		Country	
Post Office Address					
Post Office Address					
City		State		ZIP	
				Country	
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor			
Given Name (first and middle (if any))		Family Name or Surname			
Inventor's Signature				Date	
Residence: City		State		Country	
Post Office Address					
Post Office Address					
City		State		ZIP	
				Country	

Burdon Hour Statement: This form is estimated to take 0.6 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.